LOW CUT POINT SPIRAL

Faan Bornman[1], Wynand Erasmus[2], Jeantelle Rust[3] Clifford Diketane[4]
[1]Technology Manager, Multotec Process Equipment (Pty) Limited
[2]General Manager–Gravity Concentration Division, Multotec Process Equipment (Pty) Limited
[3]Research and Development Engineer, Multotec Process Equipment (Pty) Limited
[4] Engineer in training, Multotec Process Equipment (Pty) Limited

ABSTRACT

Spiral separators offer a number of advantages for fine coal beneficiation, including low operating and capital costs, operational simplicity, excellent tolerance to variation in feed conditions, low maintenance and high reliability.

Spirals typically separate efficiently at cut points between specific gravities of 1.6 and 1.8. Under more carefully controlled conditions, cut points around 1.55 are readily achievable. The most noted limitation of current spiral models is an inability to achieve cut points below these levels.

Traditionally, cut points of around 1.65 meant that the spiral's duty was to separate essentially "clean" coal particles from those with a substantial mineral component. Reducing the cut point means that the spiral has to discriminate between particles of clean coal and particles of "less-clean" coal. The test work sets out to explore the possibility of achieving this.

1. INTRODUCTION

Spiral concentrators are widely used for the beneficiation of fine coal typically the -1mm size fraction. Spiral concentrators offer a number of advantages for fine coal beneficiation including low operating and capital costs, operational simplicity, excellent tolerance to variation in feed conditions, low maintenance and high reliability.

Spirals typically separate effectively at cut points between 1.6 and 1.8 spesific gravity (SG.) Under more carefully controlled conditions, cut points around 1.55 are readily achieveable. The most noted limitation of current spiral models is the inability to achieve cut points below these levels.

Traditially, cut points at around 1.65 meant that the spiral's duty was to separate essentailly "clean" coal particles from those with a substantial mineral component. On current spiral models, coal particles in the SG range 1.2 to 1.6 are predominantly water-born. Reducing the cut point meant that the spiral now had to discriminate between paticles of clean coal and particles of "less-clean" coal. For this to happen, the coal particles have to have more contact with the trough surface to enable those denser than the new cut point to report to either the middling or reject stream.

2. **SPIRALS**

Spiral concentrators are widely used for the beneficiation of fine coal, typically in the -1 mm size fraction.

Spirals are characterised as a film concentrator, a relatively simple device used to separate particles according to size, density and shape (*Glass* et al., 1999). Spirals exhibit one of the most complex flow regimes amongst gravity separators. Spiral concentrator flows display laminar to increasingly turbulent behaviour. The primary flow is that of the slurry descending the inclined portion of the trough. Secondary flow occurs radially across the trough. During their passage through a spiral, particles are subjected to hydrodynamic drag and lift, friction, gravity and centrifugal forces.

In general, the motion of particles depends on the particle properties (size, density and shape), the operating conditions (slurry density and flow rate) and the spiral design (trough shape, inclination, number of turns) (*Holland-Batt* et al., 1984). With coal spirals, accumulation of relatively lights particles in the middle flow is likely to occur within the range of feasible operating conditions. This makes the coal spiral very suitable for separating organic contaminant from soil when these are sufficiently liberated. The concentration of contaminants in the middle flow can be optimized by adopting splitter positions. A deviation from optimum operating conditions influences separation performance such as an increase in density of separation and a lower sharpness of separation.

3. **SX10 LOW CUT POINT SPIRAL**

The SX7 spiral model has traditionally been used for coal cleaning in North-America. The SX7 is a seven turn, wide diameter spiral with a "drop-in" repulper and off-take to the centre column. The SX7 was used as a benchmark at 35% solids by mass. Figure 1 shows the SX7 spiral model:

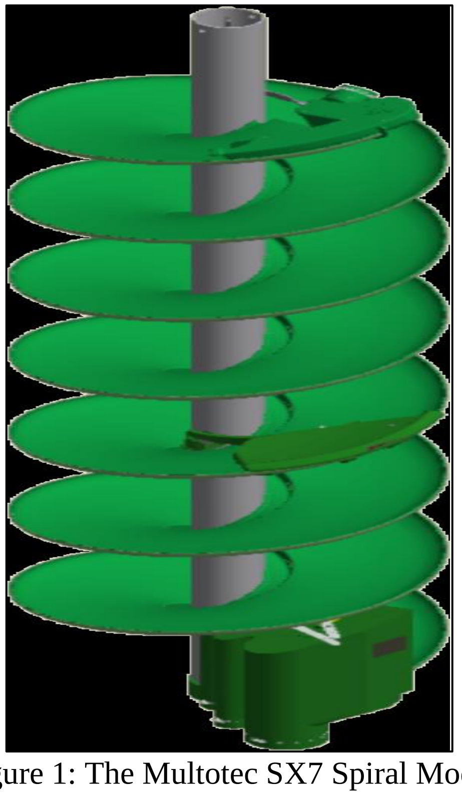

Figure 1: The Multotec SX7 Spiral Model

The SX10 spiral model is a longer version of the SX7. This is to allow for an increase in residence time. The spiral has two “drop-in” repulpers and off-takes to the centre column.

Figure 2 shows the SX10 spiral model:

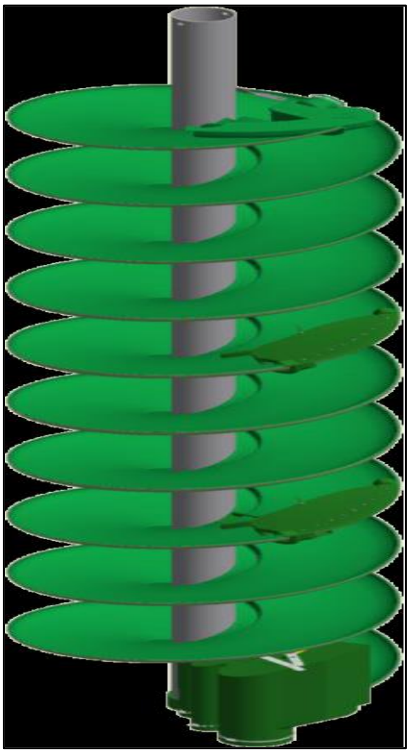

Figure 2: The Multotec SX10 Spiral Model

The theory behind the low cut point is that the gangue or mineral-containing particles are removed from the spiral trough. This opens up available separation surface and the bed “slides down” towards the centre column. Instead of having a trough filled with mineral-rich particles and coal, particles of “less clean” and clean coal are now present in the trough. Figure 3 shows the principle:

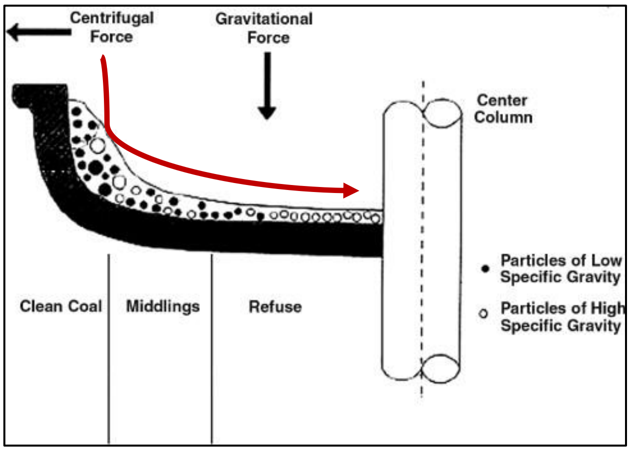

Figure 3: Operation Principle of the SX10 Spiral

4. EXPERIMENTAL PROCEDURE

The SX7 at 35% solids (by mass) was used as a benchmark for the test work. Approximately one ton of coal was obtained from Goedgevonden Colliery in South Africa. The particle sizes were in the range typically being used for spiral feed. The SX10 was compared to the SX7 at solids concentrations as per Table 1 below:

Table 1: Test Work Matrix

Spiral	Solids by Mass (w/w %)	Dry Solids Throughput (tph)
SX7	35	3.0
SX10	35	3.0

Each of the runs described above was repeated three times in order to ensure repeatability.

The splitters on the spiral was set at ± 270 mm, thus ensuring only the clean coal was fed to the repulper, and allows to gravity separate further down on the trough. Figure 4 shows the splitter in position:

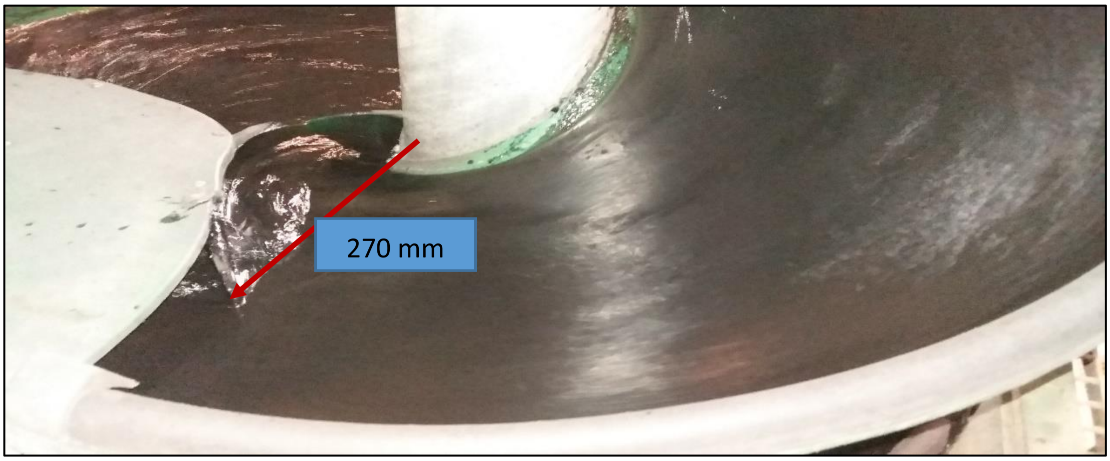

Figure 4: Spiral Splitter Settings

The 270 mm setting corresponds to cutting at mouth organ fraction E as per Figure 5 below:

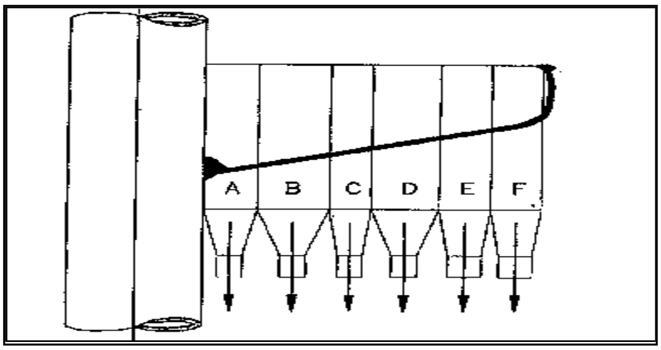

Figure 5: Mouth Organ Product Box

5. RESULTS

5.1 Spiral Feed

Figure 6 shows the spiral feed Particle Size Distribution (PSD):

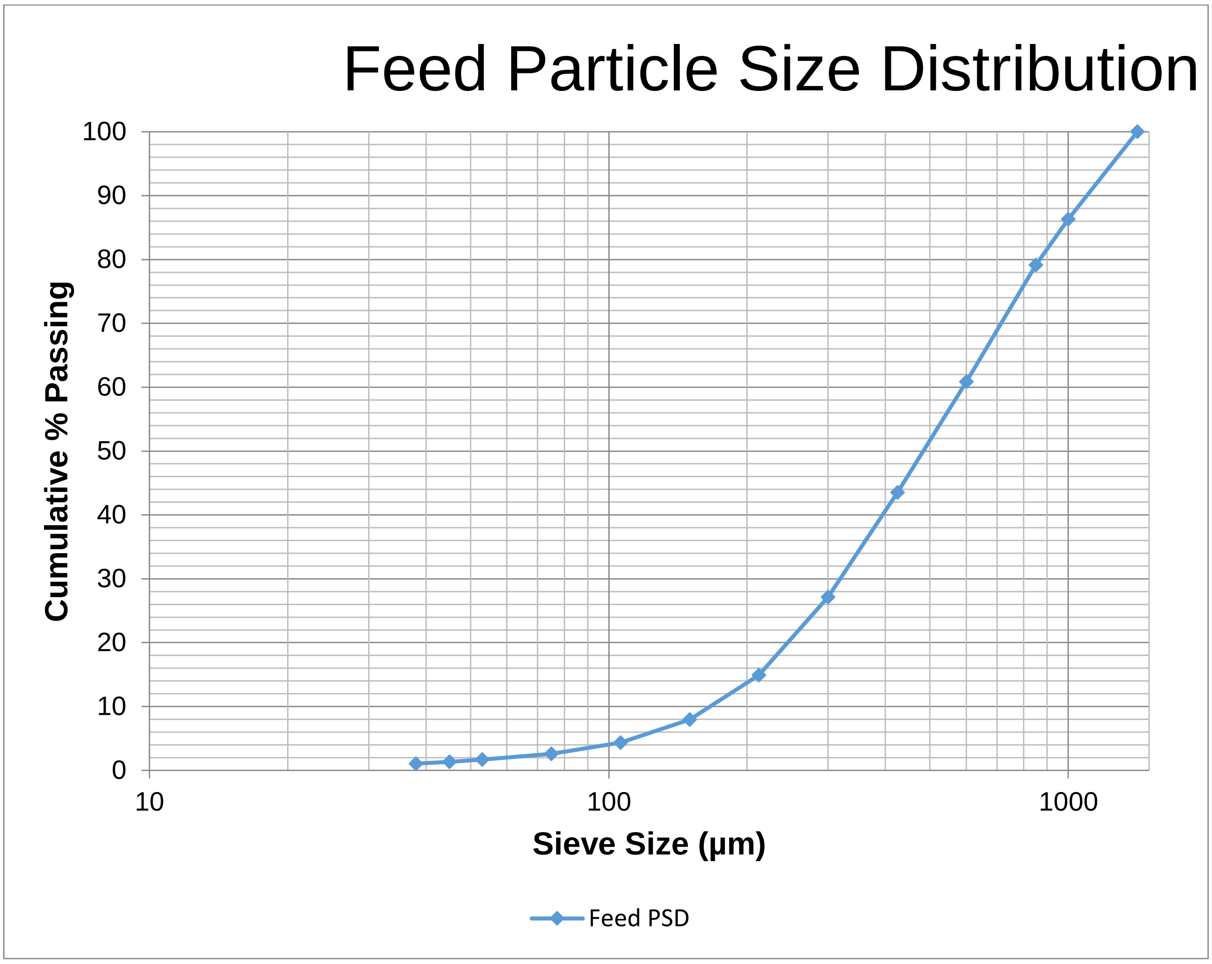

Figure 6: Spiral Feed PSD

Table 2 shows the chemical analysis results of the spiral feed:

Table 2: Spiral Feed Chemical Analysis Results

	CV (MJ/kg)	**Sulphur (%)**	**Ash (%)**
SX7	22.45	0.34	25.18
SX10	21.88	0.45	26.66

5.2 CV versus Mass Yield

Figure 7 shows the Calorific Value versus the mass yield for the spirals tested.

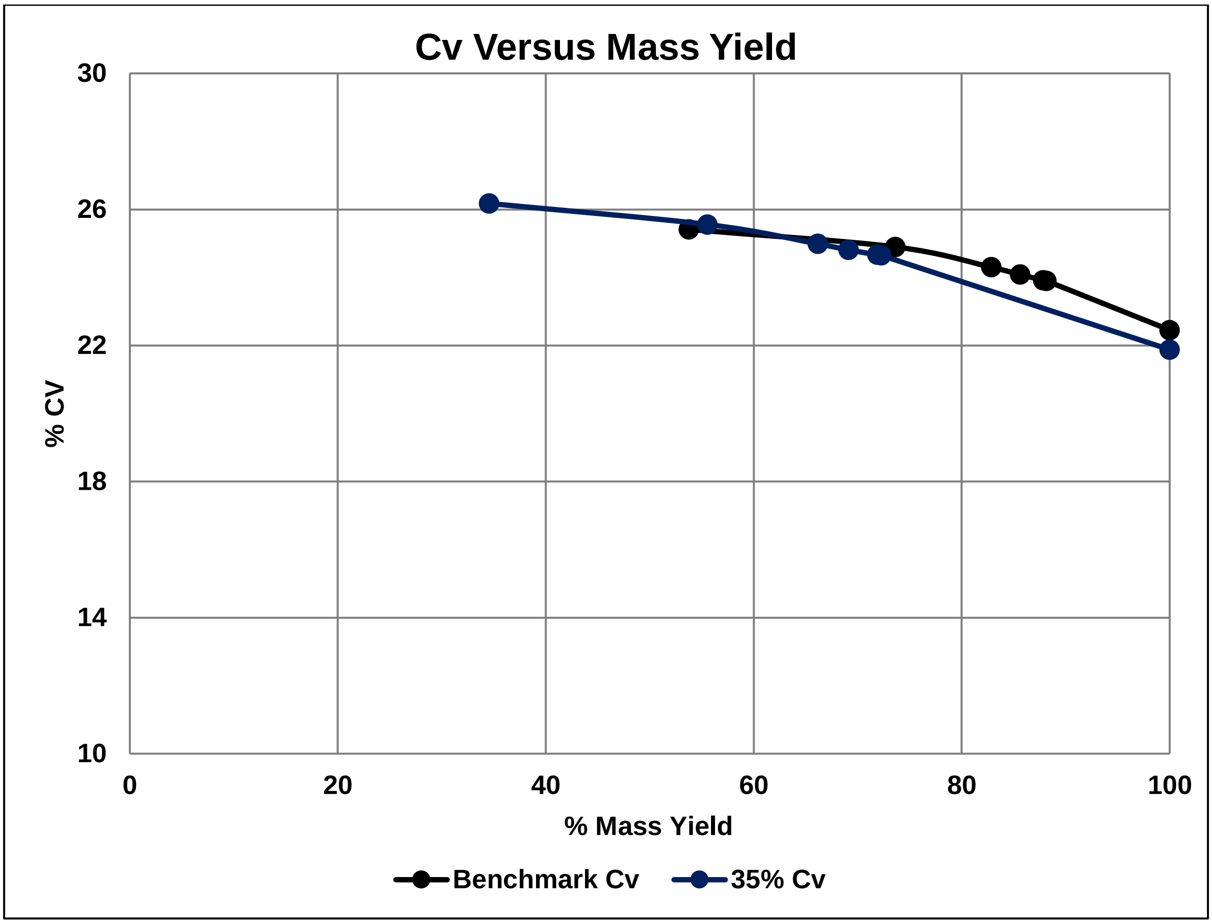

Figure 7: % CV versus mass yield

5.3 Ash versus Mass Yield

Figure 8 shows the percentage Ash versus the mass yield for the different spirals.

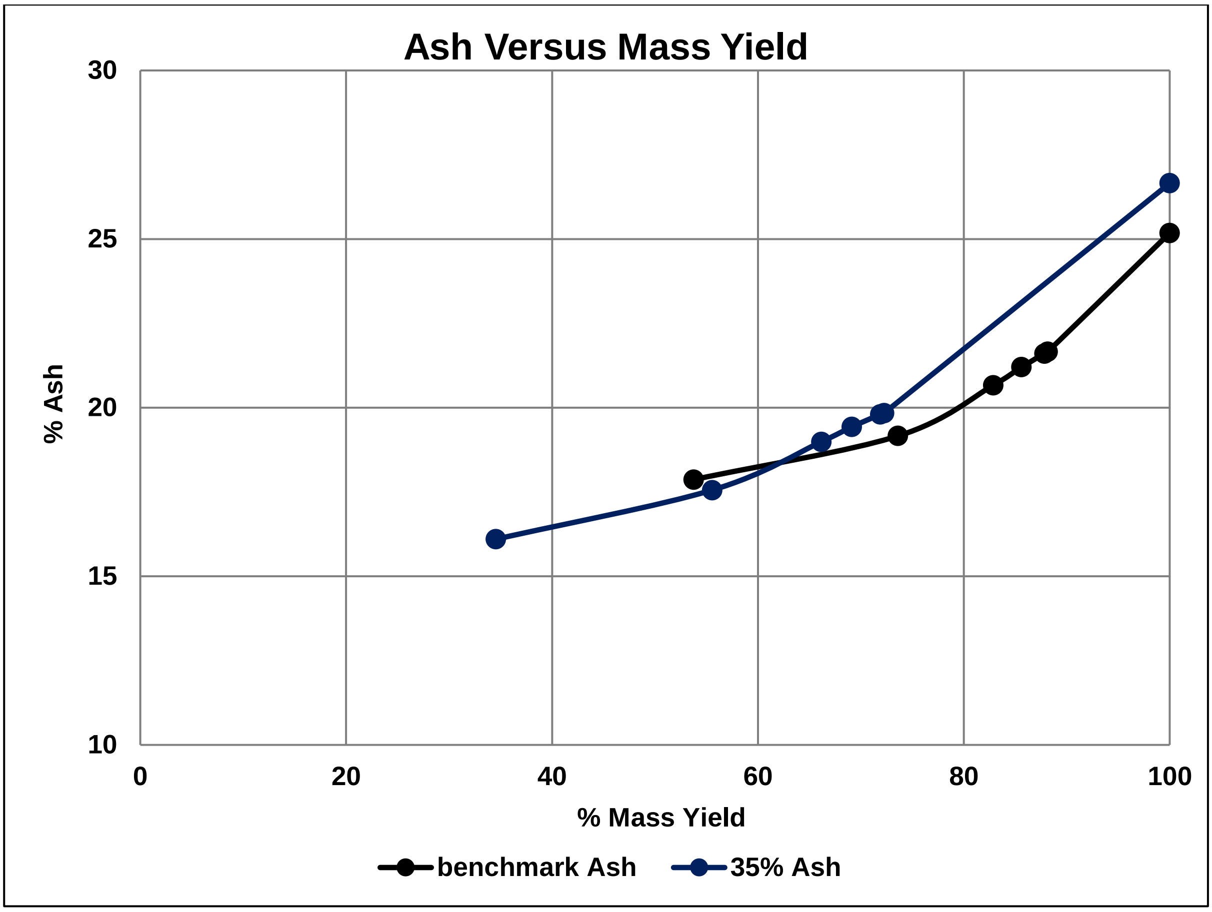

Figure 8: % Ash versus mass yield

5.4 Sulphur versus Mass Yield

Figure 9 shows the Sulphur content versus the mass yield.

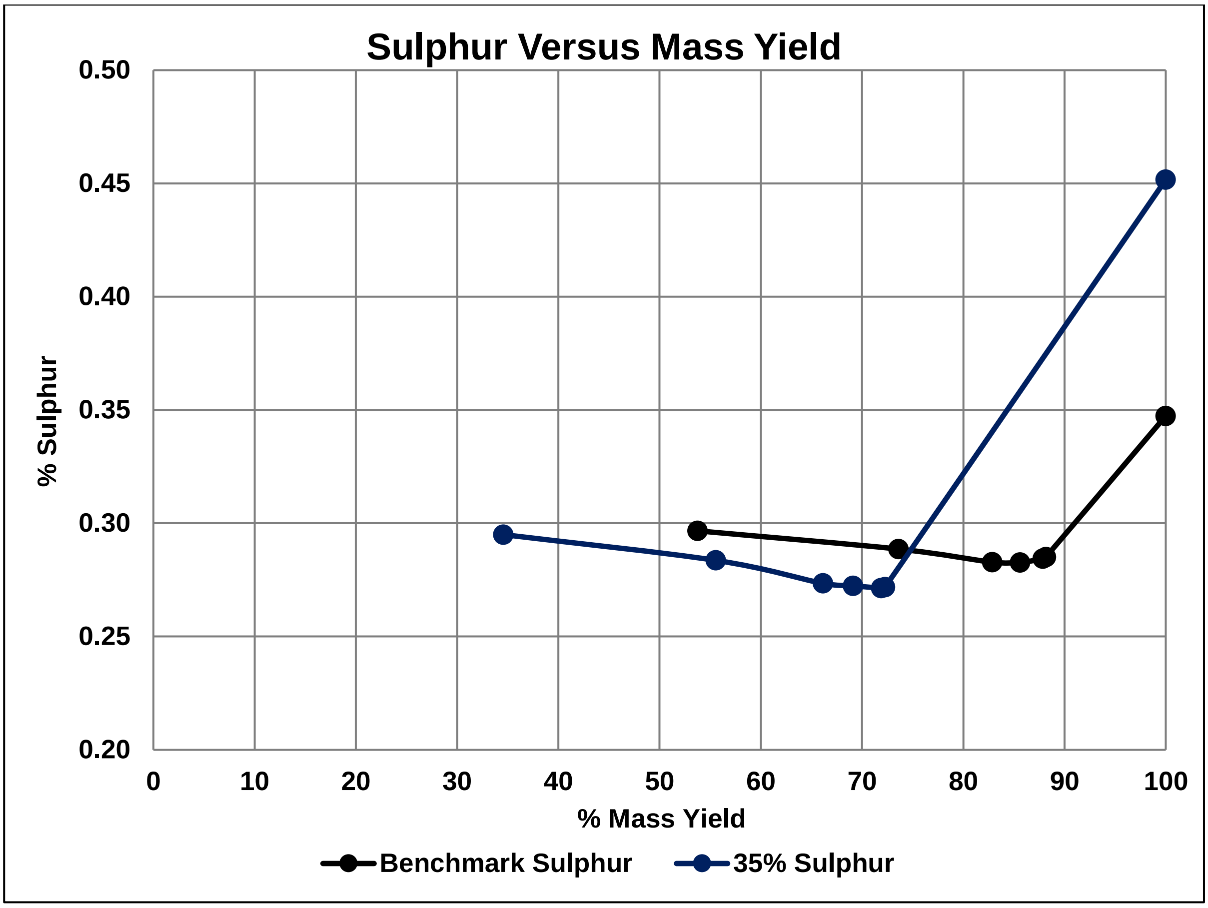

Figure 9: % Sulphur versus mass yield

Table 3 shows the mouth organ product box (fraction F) results of the spiral test work:

Table 3: Mouth Organ Product Box Results

Spiral	Solids Concentration (w/w %)	Mass yield (%)	CV (MJ/kg)	Sulphur (%)	Ash (%)
SX7	35	53.73	25.41	0.30	17.87
SX10	35	34.60	26.18	0.30	15.50

5.4 Cut point

Ramsaywok et al., (2017) said that over the last few years a “low-cut” spiral technology has entered the market. The introduction of the low-cut spiral produced is a recent opportunity for fine coal beneficiation.

Figures 10 & 11 show the Partition curve for the SX7 and SX10 spirals.

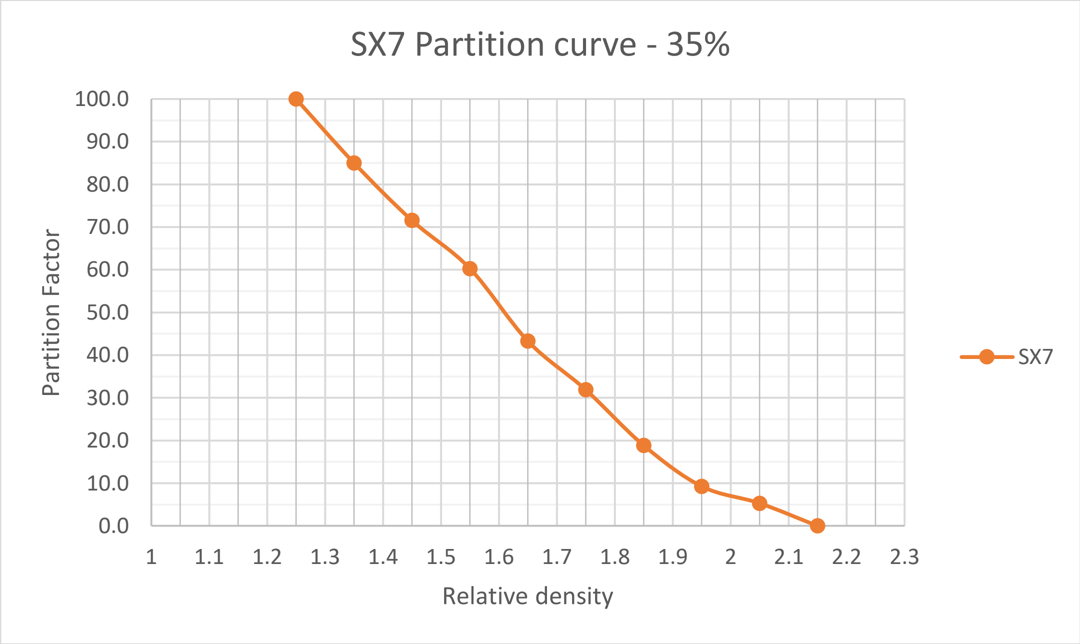

Figure 10: Partition curve for the SX7 spiral

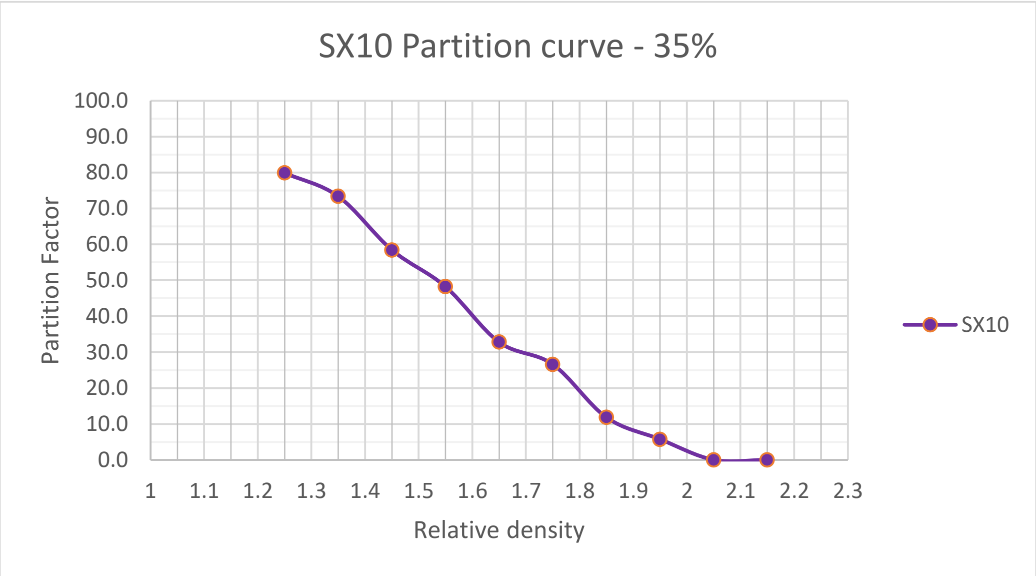

Figure 11: Partition curve for the SX10 spiral

Figure 11 shows a lower cut point for the SX10 spiral, but with more misplacement of product to discard. The cut points and mass yields achieved were in line with the values obtained by *Ramsaywok* et al, (2017). A float sink analysis shows a product yield of ±40% and discard yield of ±60% on both spirals.

6. CONCLUSIONS

The CV values of the feed coal increased from ±22 MJ/kg to 25.4 MJ/kg and 26.1 MJ/kg for the SX7 and SX10 respectively. The clean coal values mentioned above was for fraction F only.

The ash content of the SX7 was lowered from 25.18% in the spiral feed to 17.87% in the product. In the case of the SX10, the ash was lowered from 26.66% to 15.50% at 35% solids concentration.

A significant difference in mass yield is noted for the product between the SX7 and SX10. The average mass yield for the SX10 was 34.60% for fraction F versus 53.73% for the SX7.

The test work shows there is a drop in mass yield in order to obtain a lower ash content in the final product. The double off-take on the SX10 spiral has removed more gangue or mineral-containing particles in comparison to the SX7.

The SX7 had a cut point of 1.61 versus 1.53 for the SX10. More misplacement of product to discard followed on the SX10. The imperfection or EPM value for the SX10 was 0.22 versus 0.19 for the SX7 spiral. At 40% solids concentration the SX10 achieved a cut point of 1.49.

7. REFERENCES

Glass, H.J., Minekus, N.J. and Dalmijn, W.L. 1999. Mechanics of coal spirals. *Minerals Engineering*, March 1999, 12(3): 271-280.

Holland-Batt, A.B., Hunter, J.L. and Turner, J.H. 1984. The separation of coal fines using flowing-film gravity concentration. *Powder Technology*, 40(1-3): 129-145.

Ramsaywok, P. and Mathumbu, P. 2017. A straight up single pass comparison of a low-cut spiral and a conventional spiral in the South African coal industry. *Southern African Coal Processing Society*, Coal Processing – the key to profitability, 22-24 August 2017.